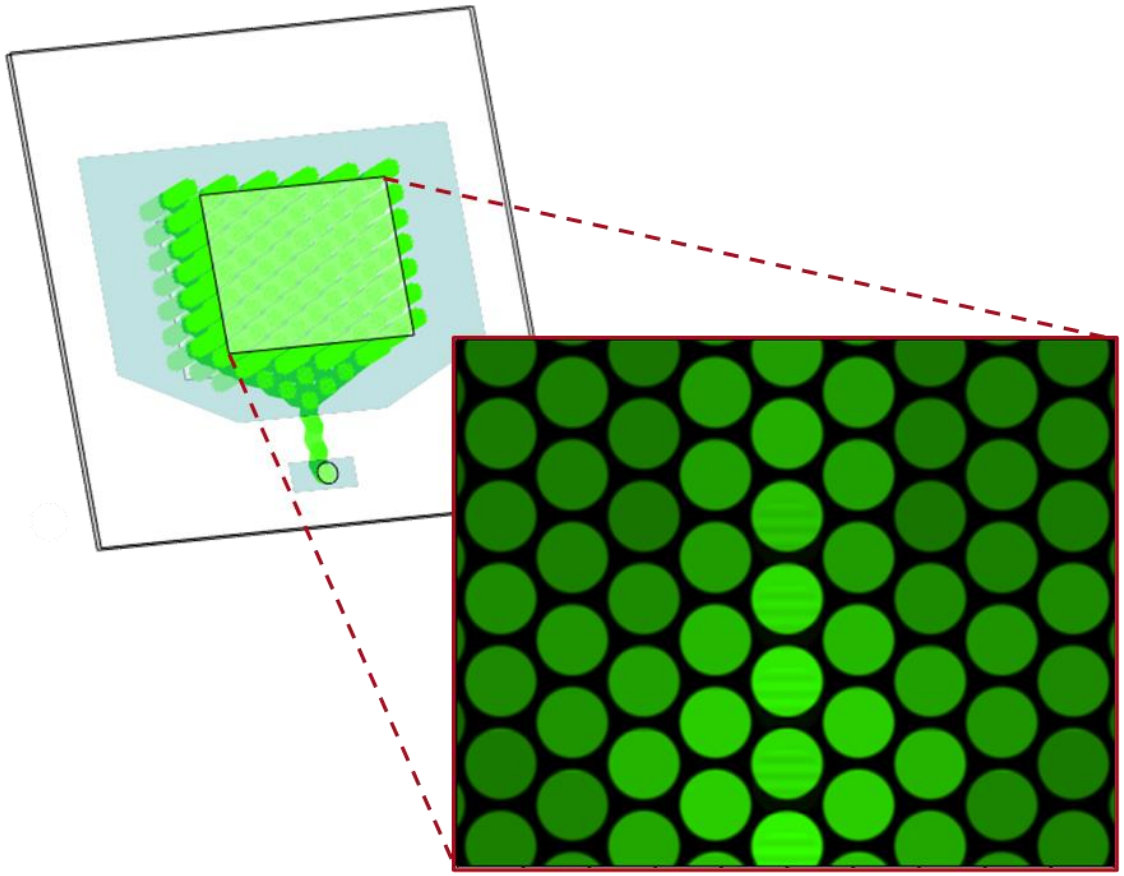
Lightguide with 2D-Periodic Grating Structures (Diamond-Shaped) Based on Patent by Wave Optics

Abstract



Most innovative AR & MR devices nowadays are based on lightguide or waveguide systems in combination with microstructures to couple light in and out. VirtualLab Fusion is capable of detailed modeling of such devices by applying our unique physical optics approach, including all effects (e.g. coherence, polarization and diffraction). We demonstrate this capability by modeling a device mentioned in patent WO2018/178626, consisting of complex 1D- and 2D-perodic grating structures.

Modeling Task: Approach from Patent WO2018/178626

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(54) Title: WAVEGUIDE FOR AN AUGMENTED REALITY OR VIRTUAL REALITY DISPLAY

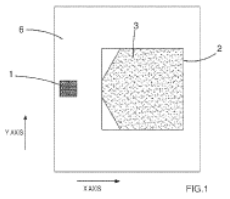

FIG.1

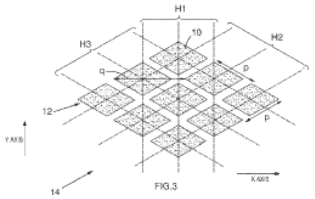

FIG.3

(57) Abstract: A waveguide is disclosed for use in an augmented reality or virtual reality display. The waveguide includes a plurality of optical structures (10, 20, 30, 40, 50, 60, 70, 80) exhibiting differences in refractive index from a surrounding waveguide medium. The optical structures are arranged in an array to provide at least two diffractive optical elements (H1, H2) overlaid on one another in the waveguide. Each of the two diffractive optical elements is configured to receive light from an input direction and couple it towards the other diffractive optical element which can then act as an output diffractive optical element, providing outcoupled orders towards a viewer. The optical structures have a shape, when viewed in the plane of the waveguide, comprising a plurality of substantially straight sides having respective normal vectors at different angles and this can effectively reduce the amount of light that is coupled out of the waveguide on first interaction with the optical structures.

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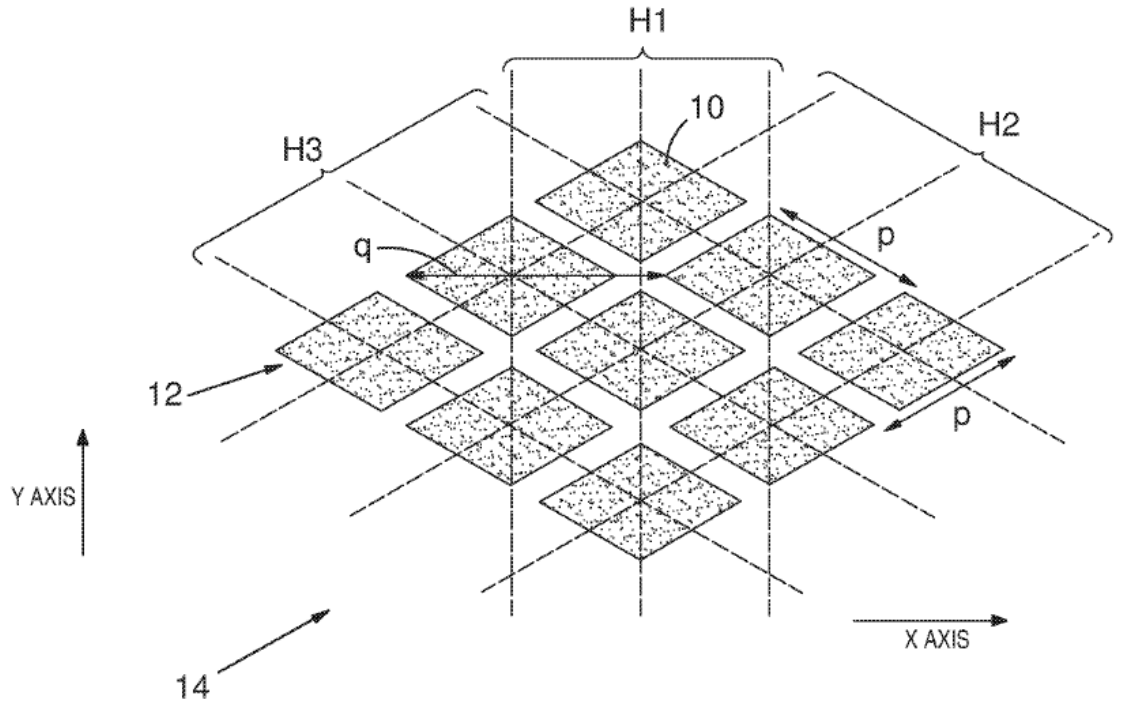
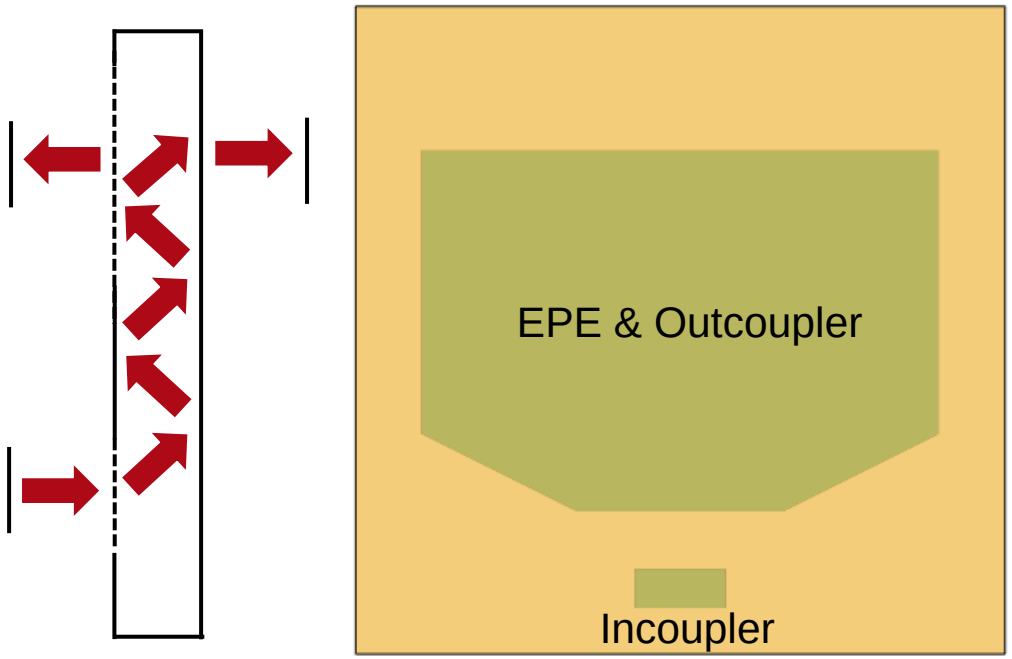


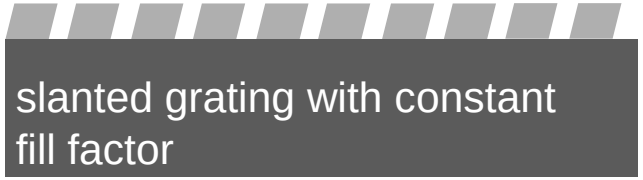
FIG.3

Task Description



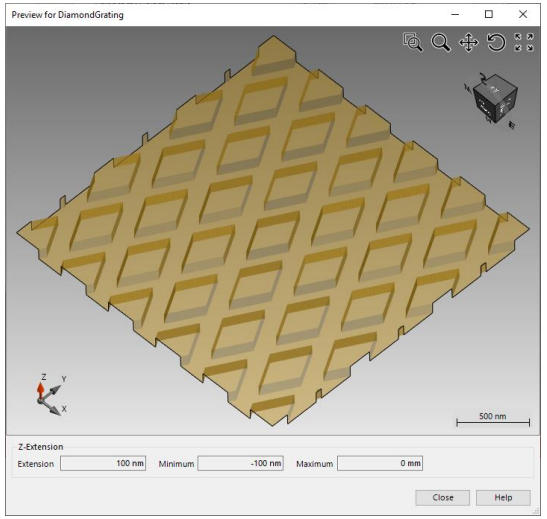
Incoupler

- slanted grating
- 400 nm period
- fill factor: 50%
- height: 400 nm



Eye Pupil Expander & Outcoupler

- 2D grating
- 461.88 nm × 800 nm period
- fill factor: 65%
- angle: 30°



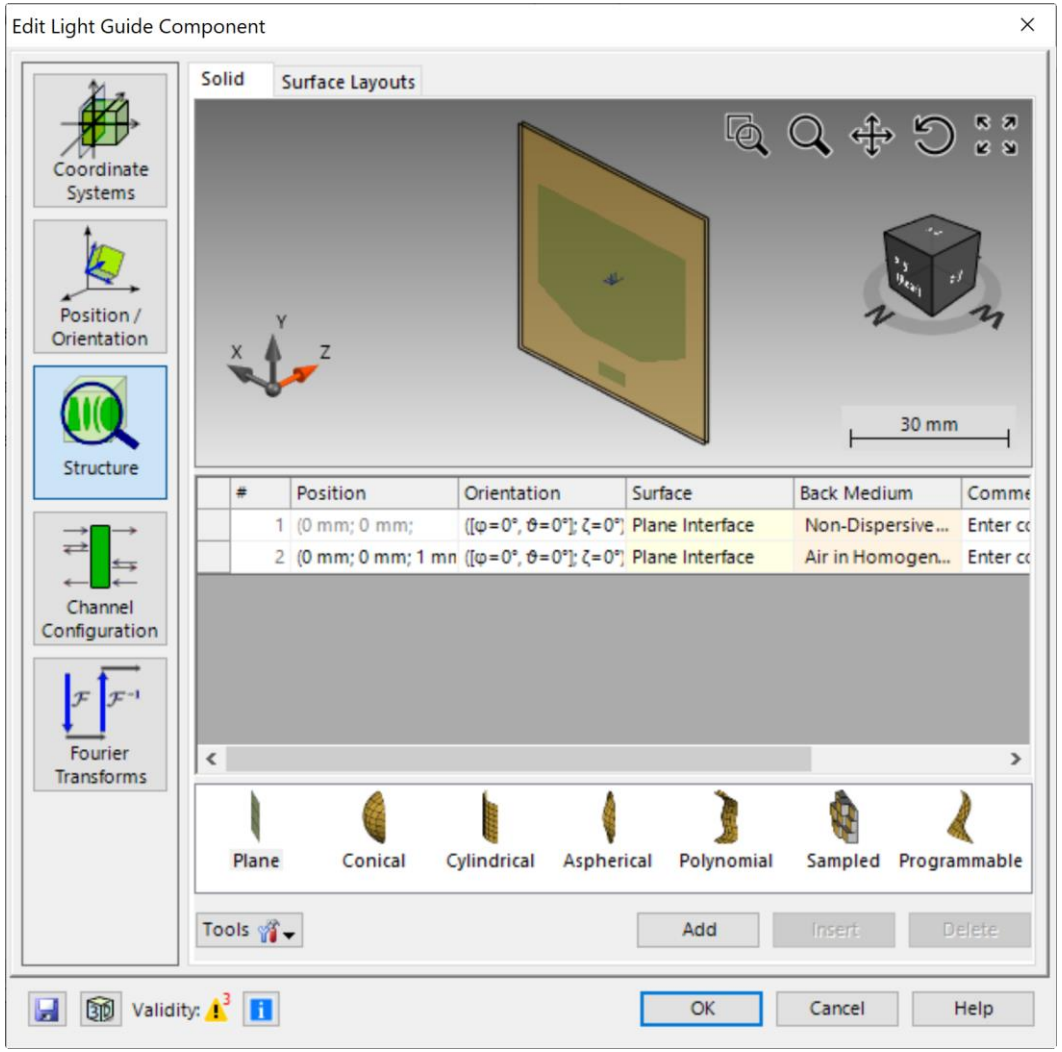
Source

- Plane Wave
- 532 nm wavelength
- 2 mm × 2 mm diameter
- linearly polarized in x-direction

Light Guide Component

With the *Light Guide Component*, systems with regions with complex shapes can easily be defined. Furthermore, these regions can be equipped with idealized or real grating structures to act as incoupler, outcoupler or exit pupil expanders. More information under:

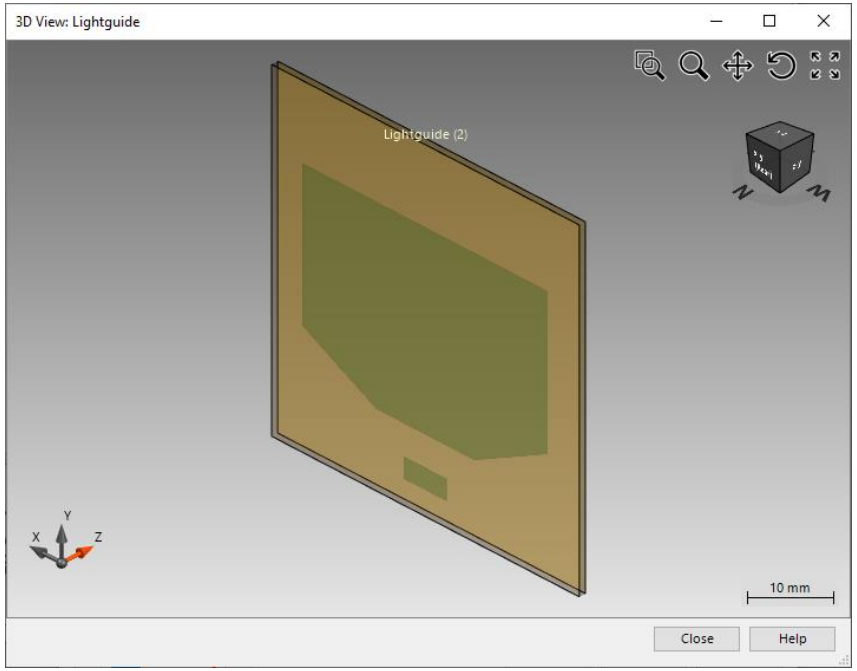
Construction of a Light Guide



Lightguide Layout

Geometric layout exhibits 2 gratings:

- Grating 1 incoupler: lamellar (1D-periodic), e.g., slanted grating
- Grating 2 EPE & outcoupler: crossed grating (2D-periodic, non-orthogonal)

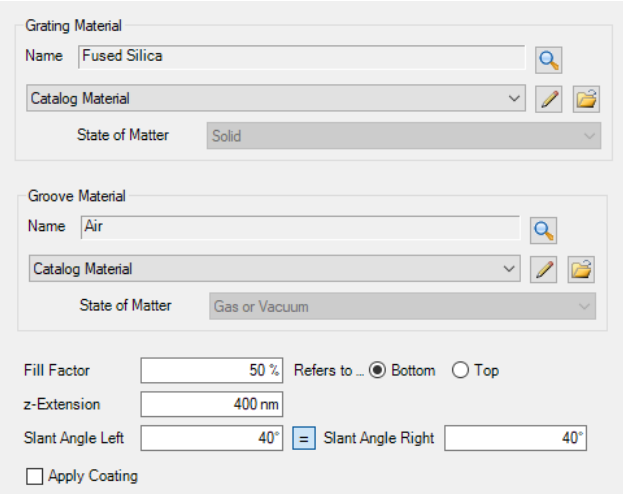


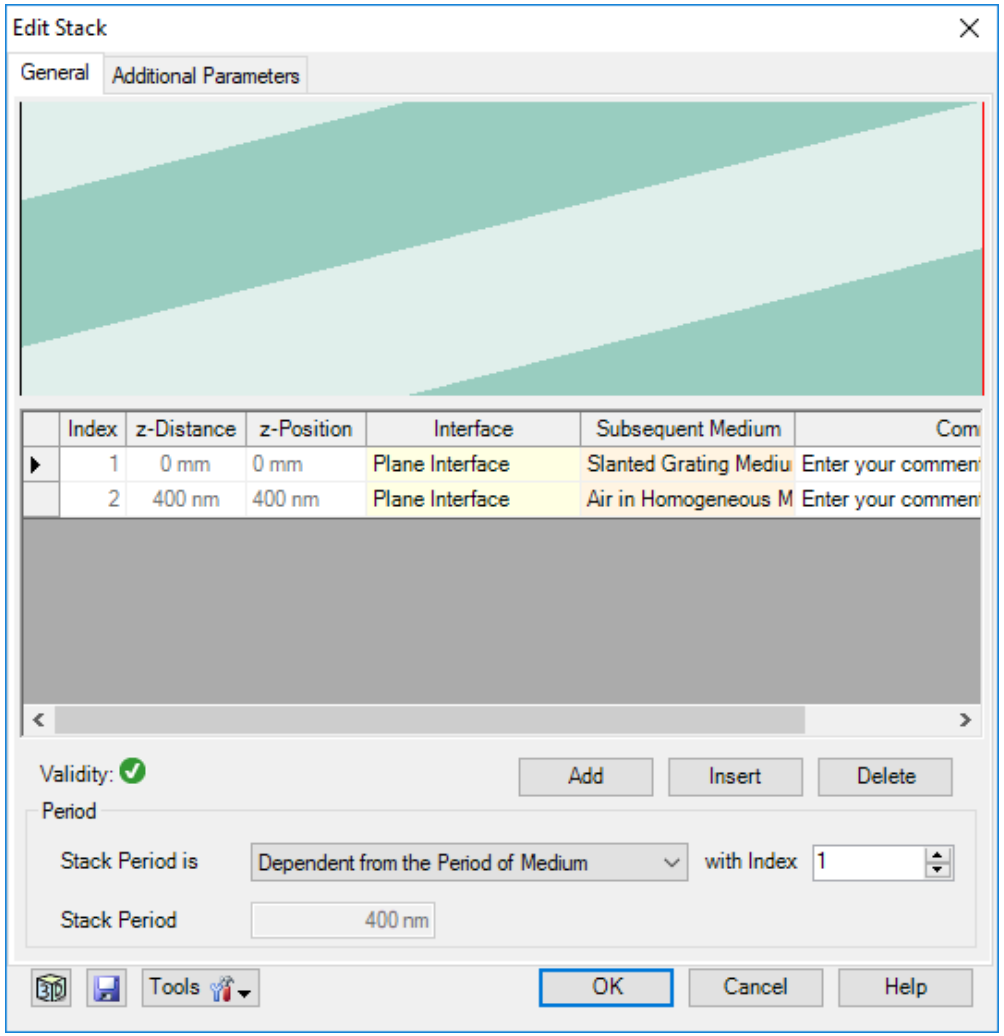
Grating #1: 1D-Periodic Grating with Slanted Ridges

1D-periodic grating structure with slanted ridges, using an inbuilt modulated medium.

Available parameters:

- period: 400 nm
- z-extension (modulation depth along z-axis): 400 nm
- fill factor (at bottom or top in non-parallel case): 50%
- slant angles of sidewalls: 40º



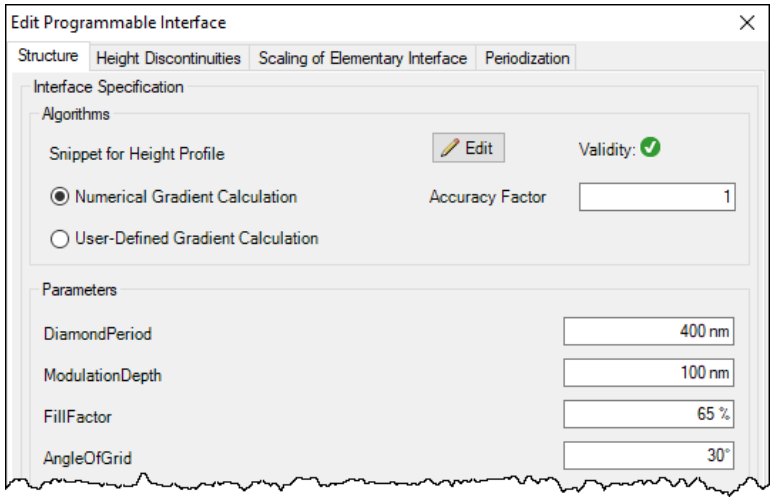


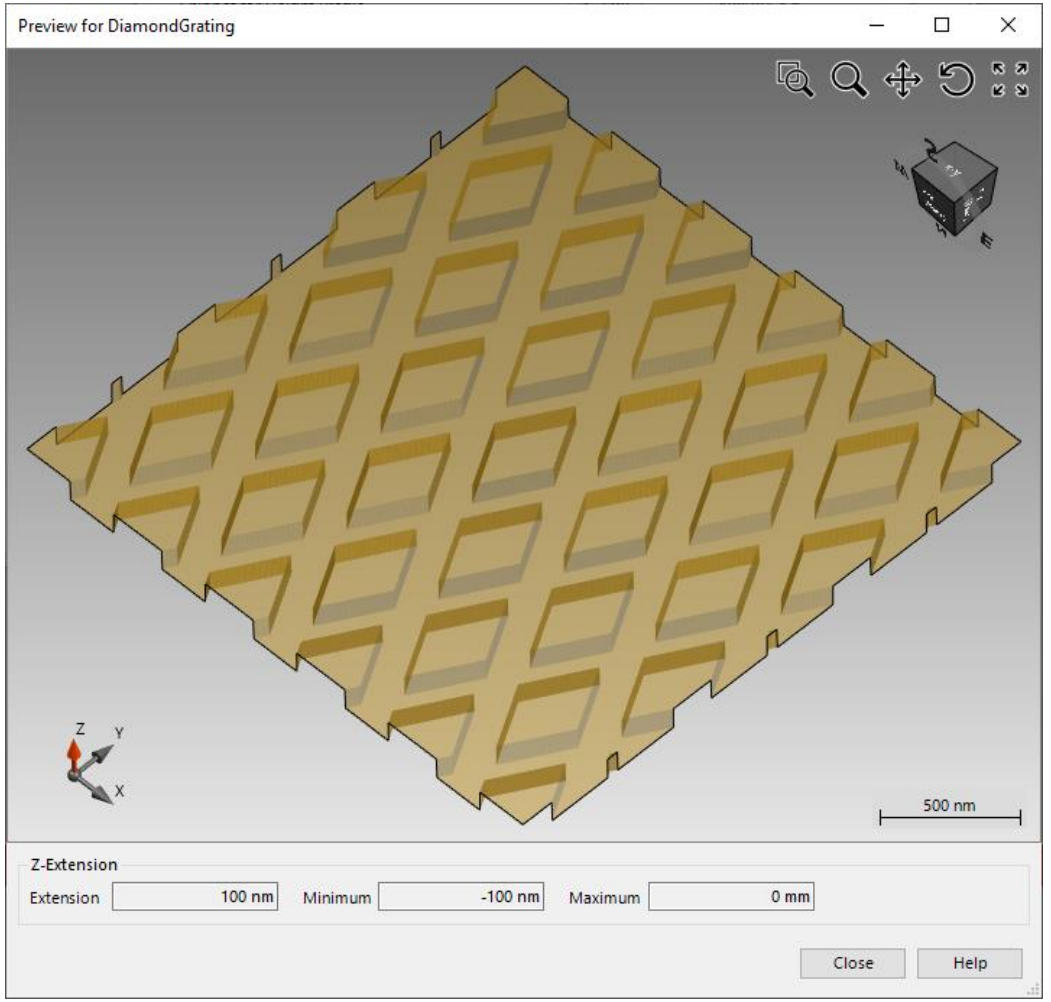
Grating #2: 2D-Periodic Grating with Diamond-Shaped Profile

Diamond-shaped (rhomboid) grating structure with non-orthogonal 2D period, realized by a customized interface.

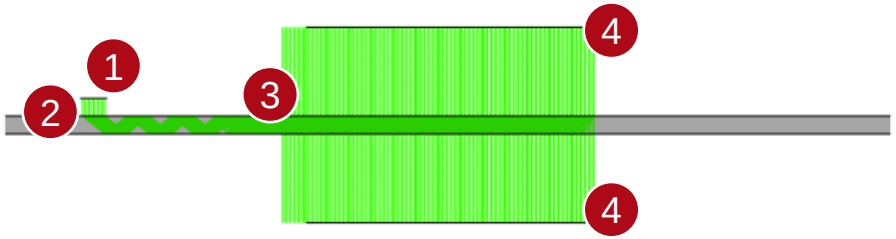
Available parameters:

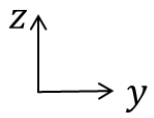
- period (in direction of diamond): (461.88 nm, 800 nm)
- Modulation depth:100 nm
- fill factor: 65%
- angle of diamond grid: 30°

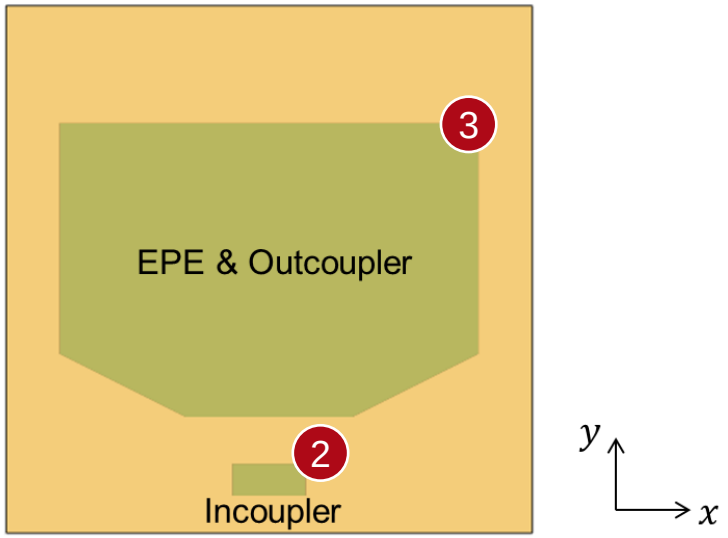




Summary – Components...

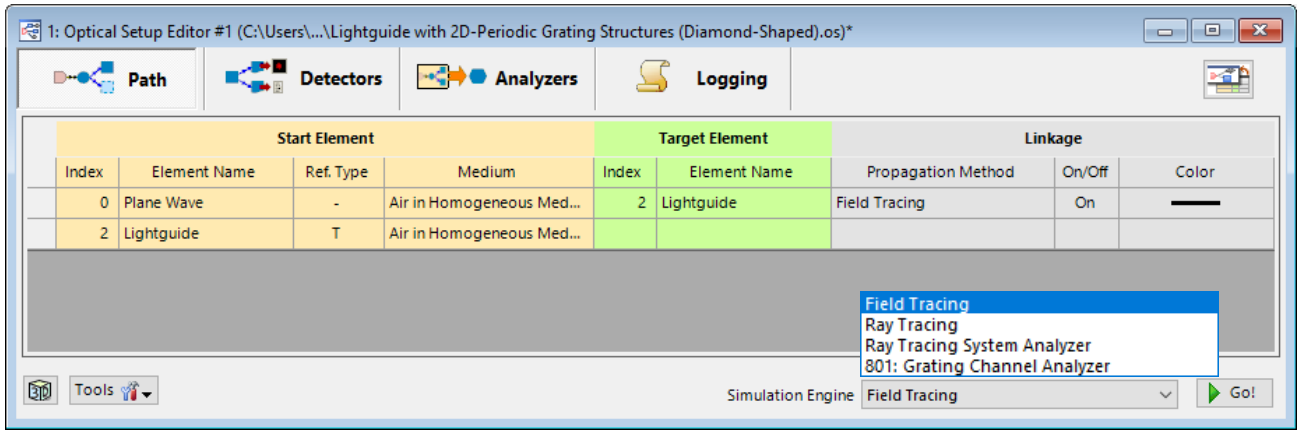






… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Value
1. Source	*Plane Wave* source	Truncated ideal plane waves
2. Incoupler	Slanted grating in *Rectangular Region*	Idealized Rayleigh matrices
3. Eye Pupil Expansion & Outcoupler	2D grating in *Polygonal Region*	Fourier Modal Method (FMM)/RCWA
4. Eye	*Camera Detector*	Energy density measurement

Detailed Analysis of System and Propagating Diffraction Orders



Various detectors and analyzers are available in VirtualLab Fusion in order to enable detailed investigation of the whole system. In this use case, *Camera Detector*, *Grating Channel Analyzer*, and *Ray Tracing System Analyzer* are mainly utilized.

The Grating Channel Analyzer, for instance, provides detailed information of the propagating diffraction orders within the lightguide. Based on its output it becomes obvious, that with lower energy threshold in the simulation, additional propagating orders are appearing (even if the contributed amount of energy is low).

Propagating orders for Component #2 (Lightguide); Surface #1; Region #1 (Grating1)

Orders in Plus-Plus Direction: ((1; 0))

with energy threshold 0.001%

Propagating orders for Component #2 (Lightguide); Surface #1; Region #2 (Grating2)

Orders in Minus-Plus Direction: ((-2; -2), (-2; 0), (-2; 2), (-1; -3), (-1; -1), (-1; 1), (0; -4), (0; -2), (0; 0), (0; 2), (1; -3), (1; -1), (1; 1), (2; -2), (2; 0), (2; 2))
Orders in Minus-Minus Direction: ((-1; -1), (-1; 1), (0; -2), (0; 0), (1; -1), (1; 1))

Propagating orders for Component #2 (Lightguide); Surface #1; Region #1 (Grating1)

Orders in Plus-Plus Direction: ((1; 0))

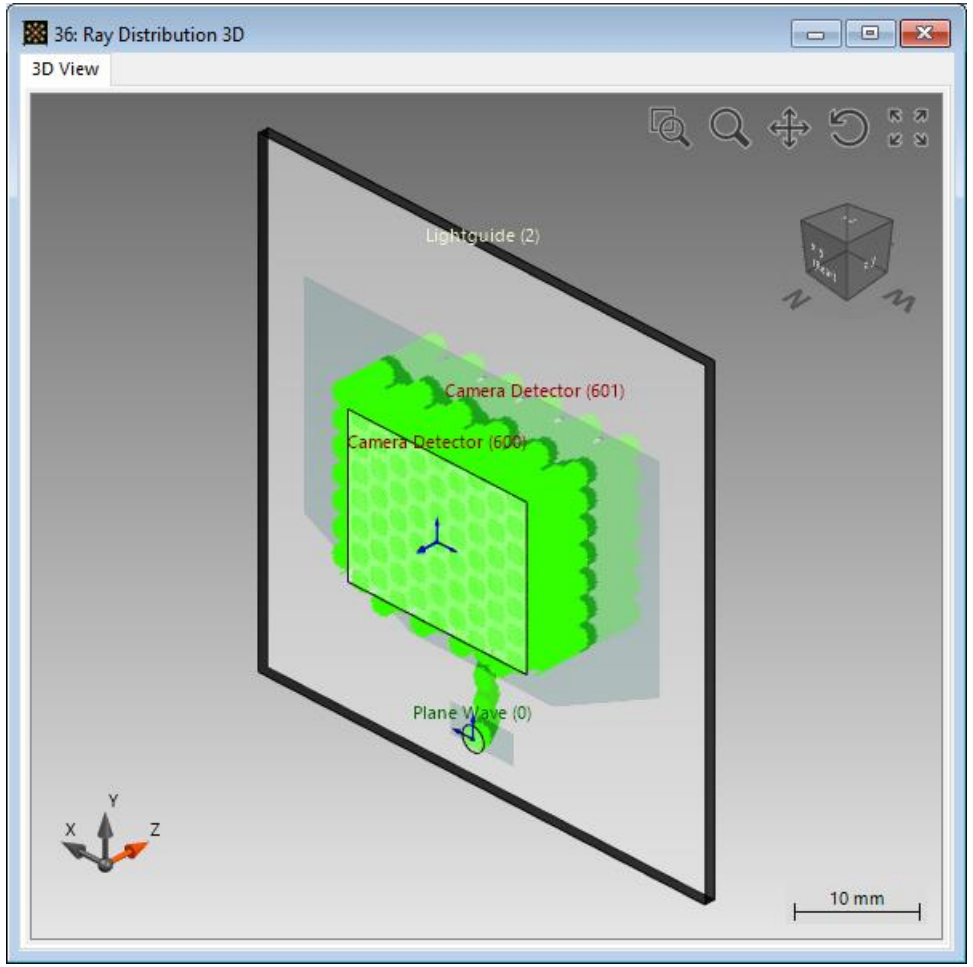
with energy threshold 0.0001%

Propagating orders for Component #2 (Lightguide); Surface #1; Region #2 (Grating2)

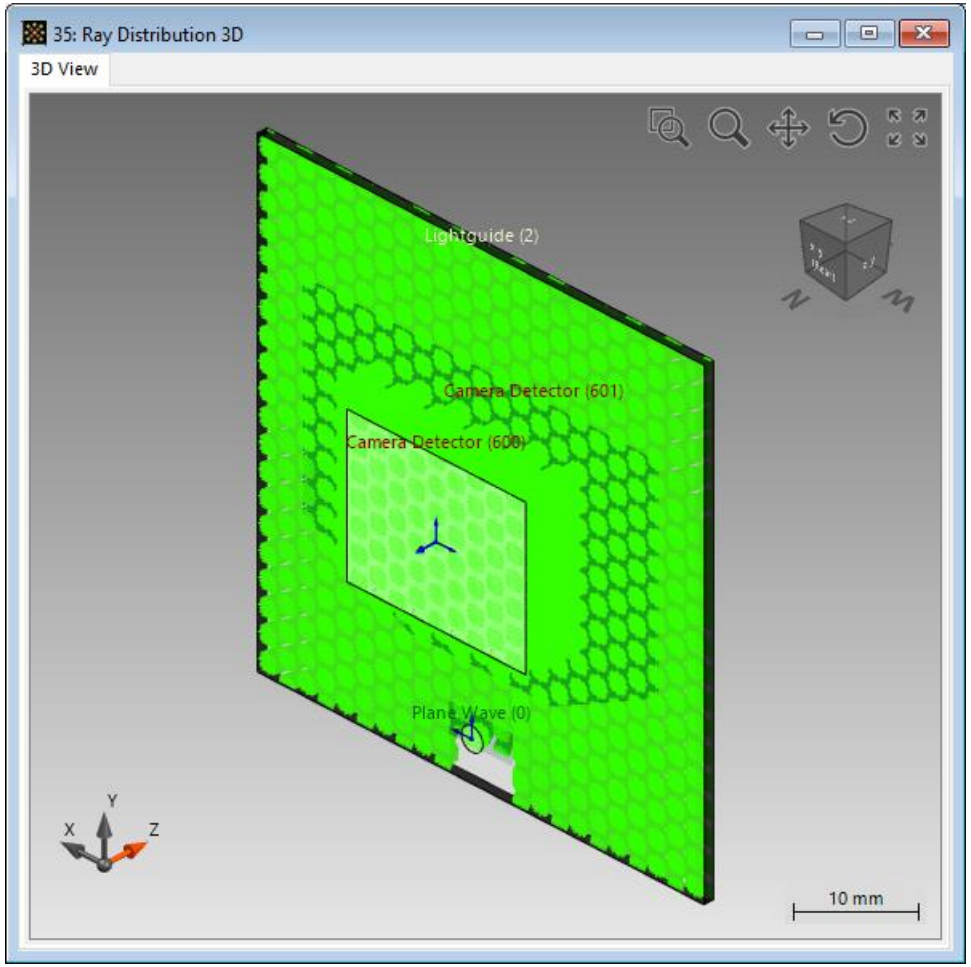
Orders in Minus-Plus Direction: ((-2; -2), (-2; 0), (-2; 2), (-1; -3), (-1; -1), (-1; 1), (-1; 3), (0; -4), (0; -3), (0; -2), (0; -1), (0; 0), (0; 2), (1; -3), (1; -1), (1; 1), (1; 3), (2; -2), (2; 0), (2; 2))
Orders in Minus-Minus Direction: ((-1; -1), (-1; 1), (0; -3), (0; -2), (0; -1), (0; 0), (0; 2), (1; -1), (1; 1))

Result: Rays in System

only light hitting the “eye-box” (camera detector):

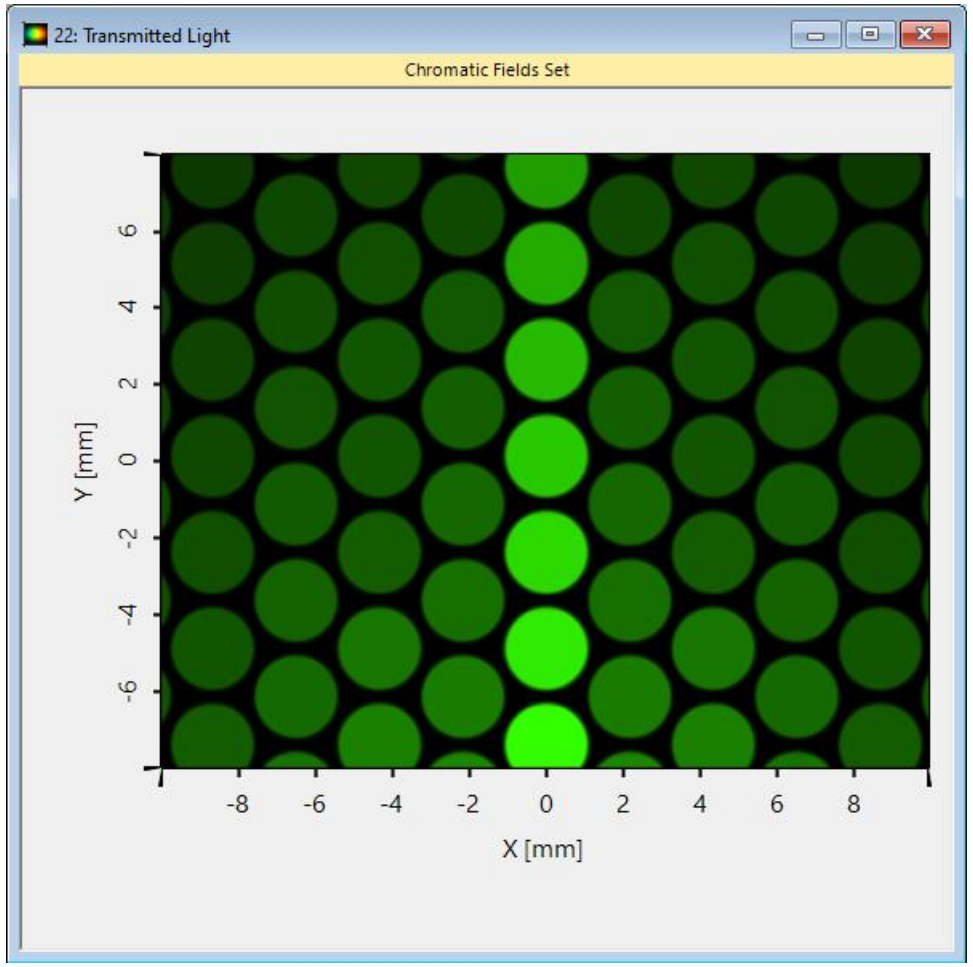


all light propagating inside the light guide:

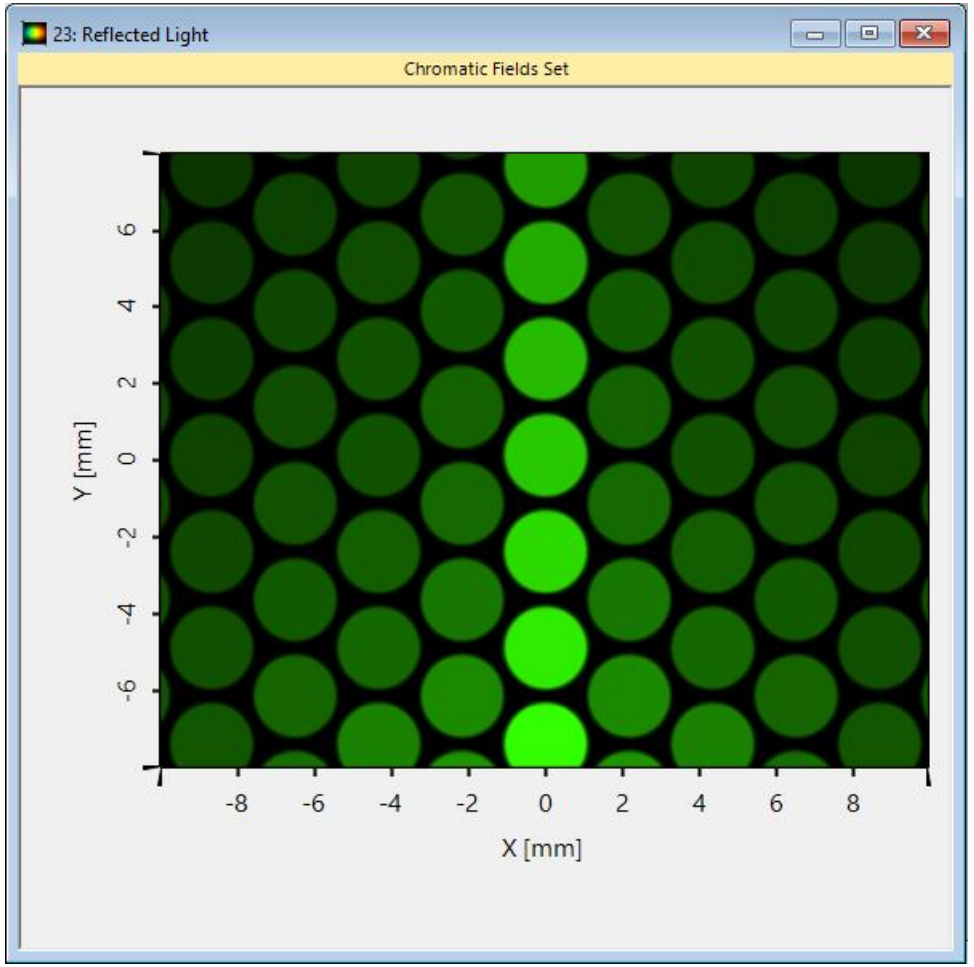


Result: Field Tracing with Energy Threshold 0.001%

transmitted light:

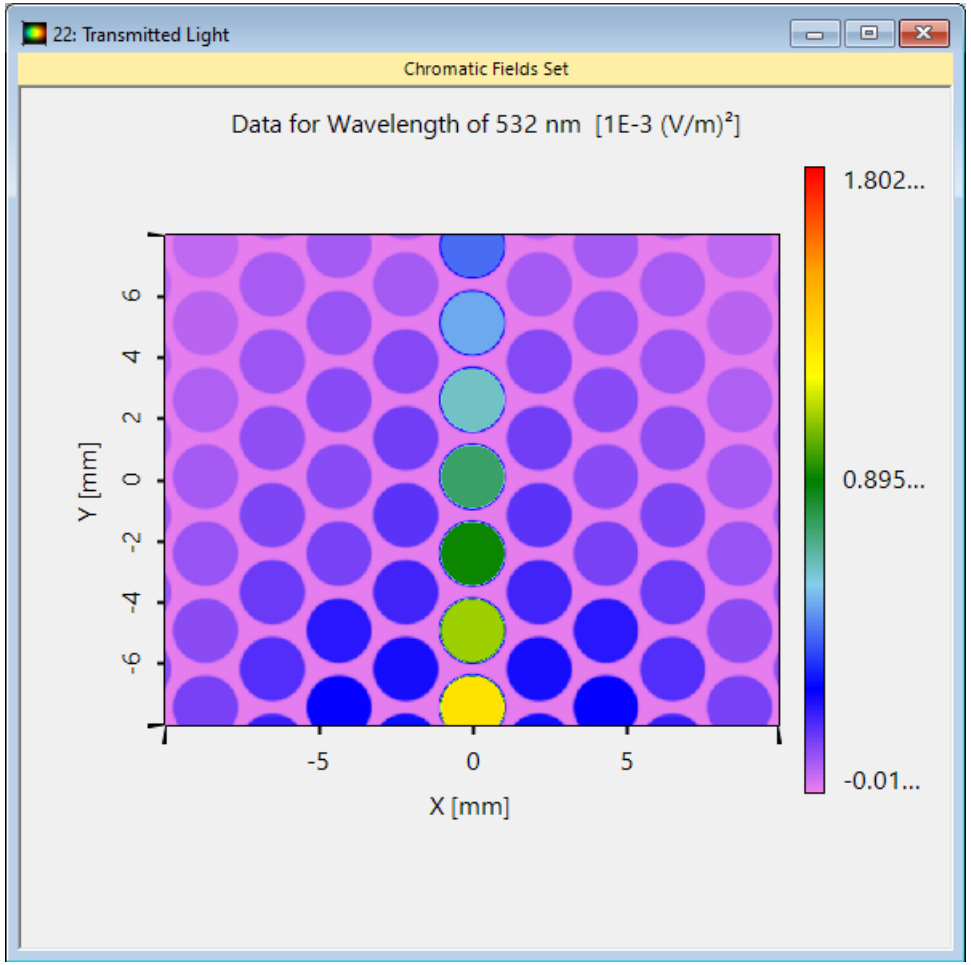


reflected light:

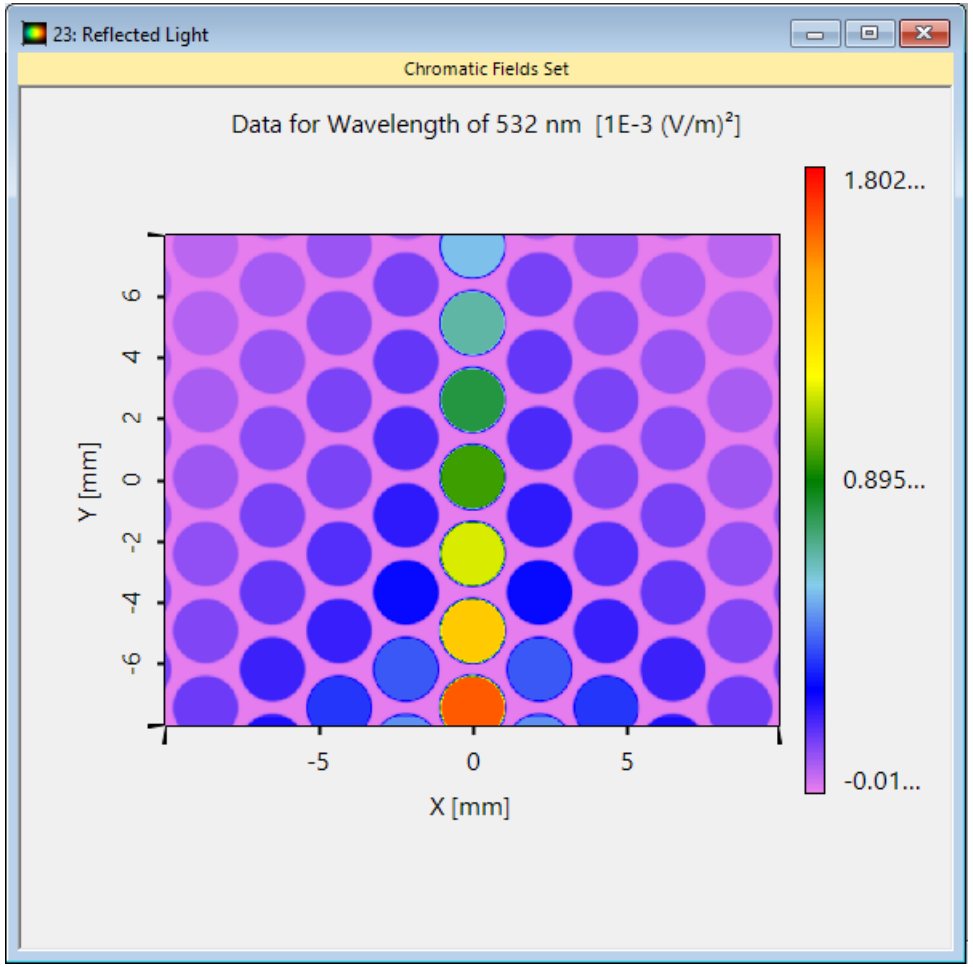


Result: Field Tracing with Energy Threshold 0.001%

transmitted light:

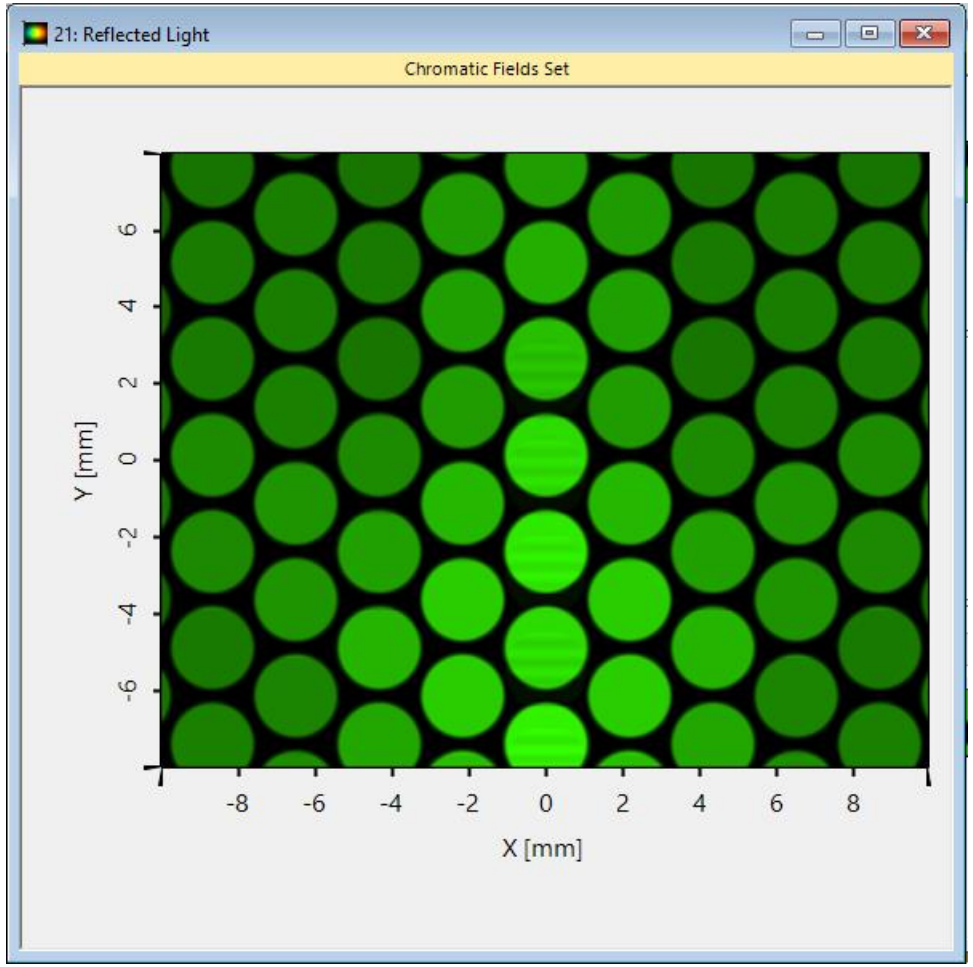


reflected light:

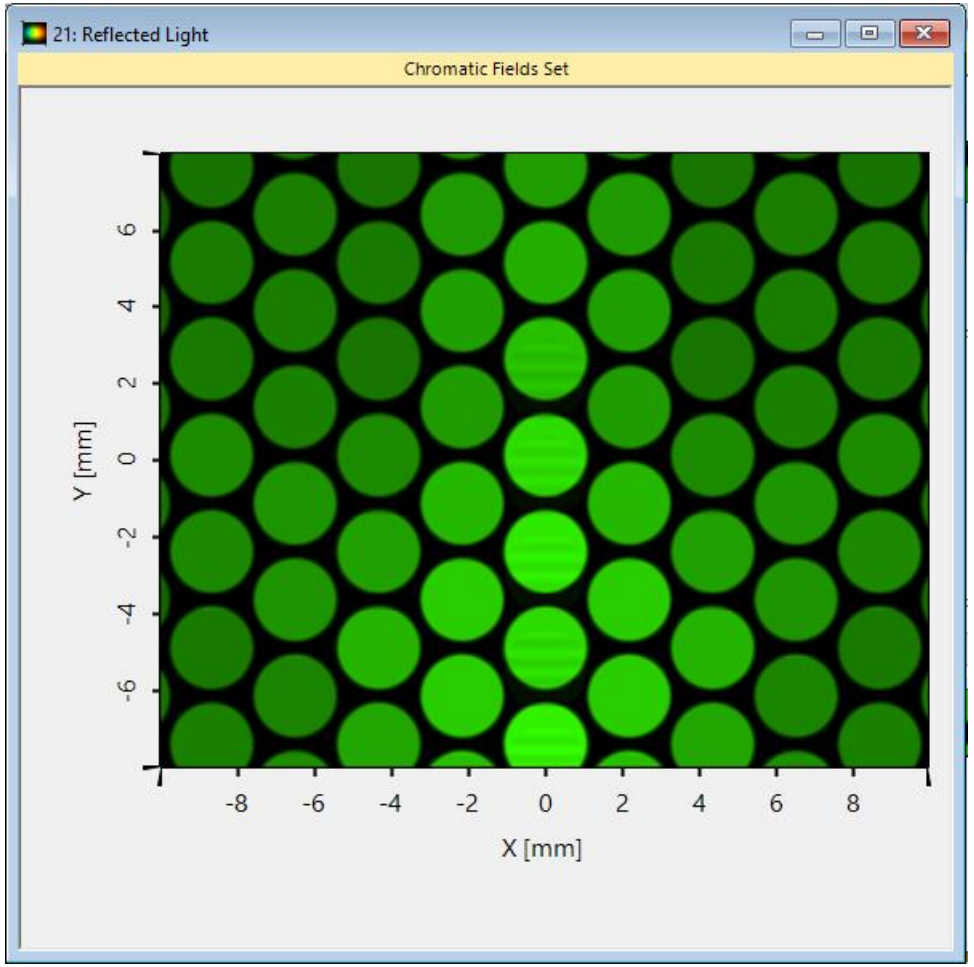


Result: Field Tracing with Energy Threshold 0.0001%

transmitted light:

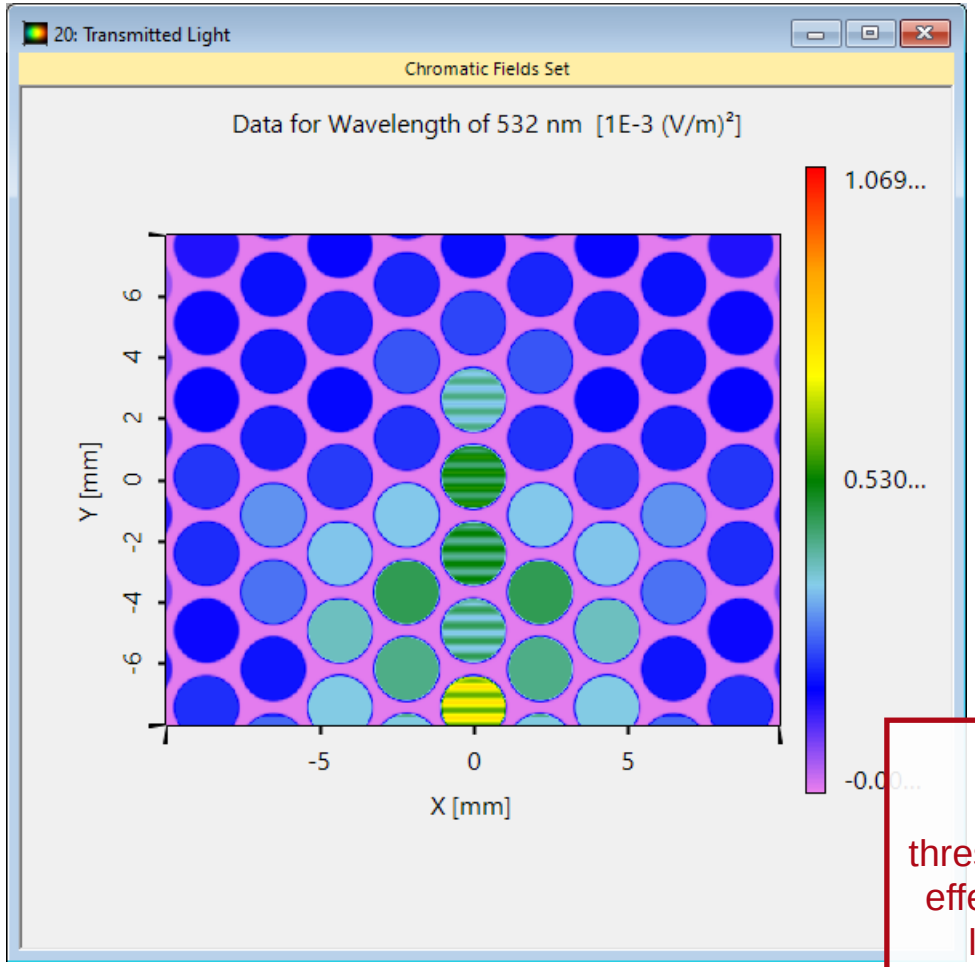


reflected light:

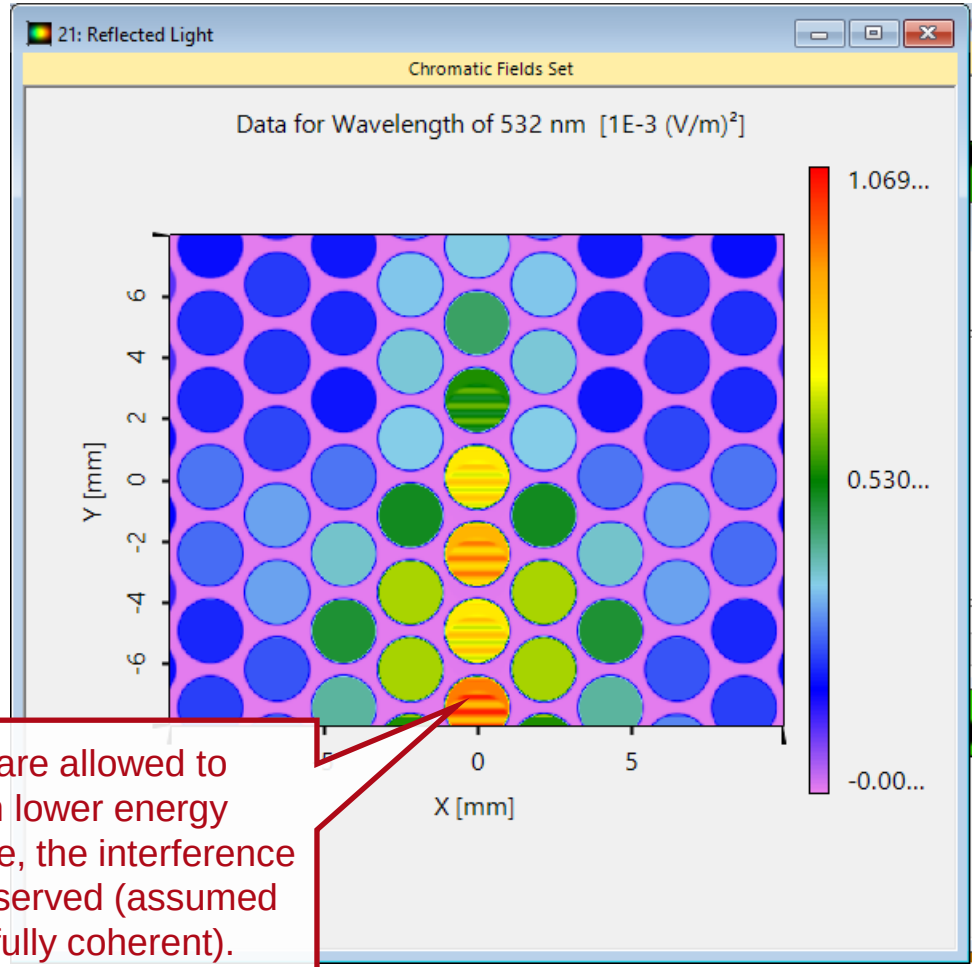


Result: Field Tracing with Energy Threshold 0.0001%

transmitted light:

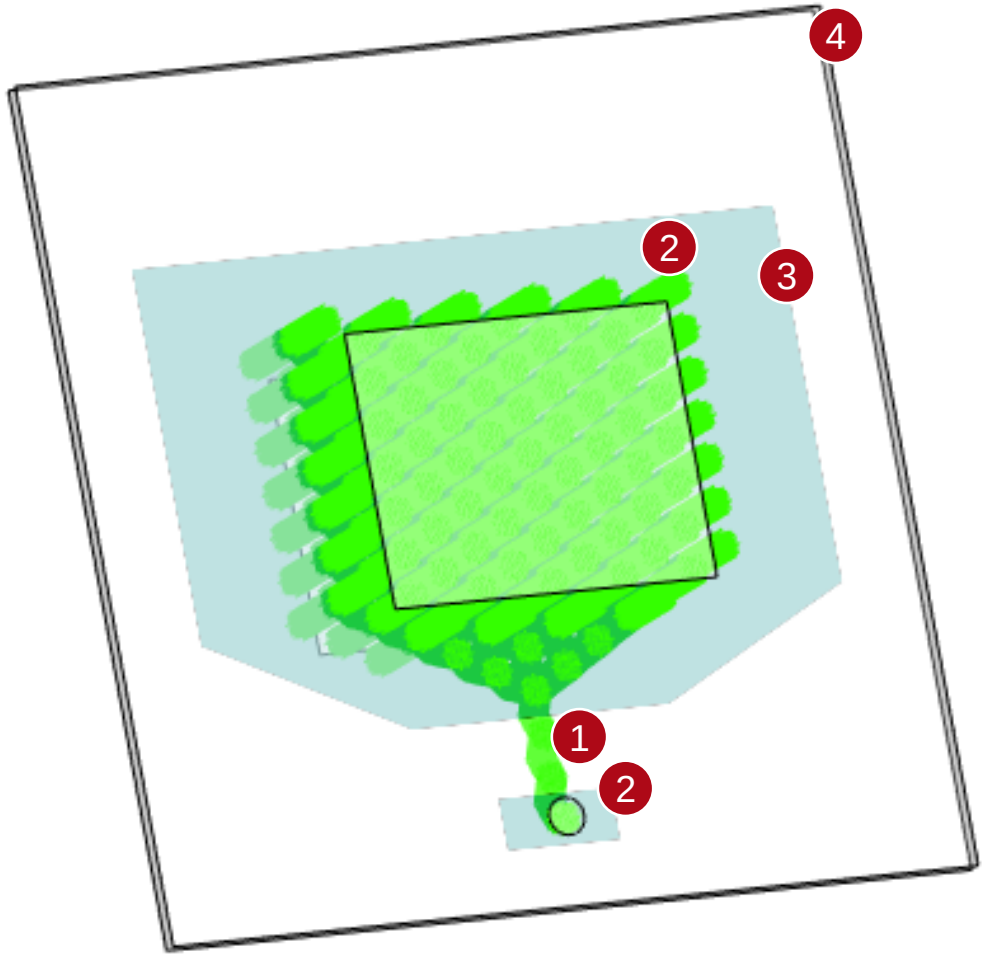


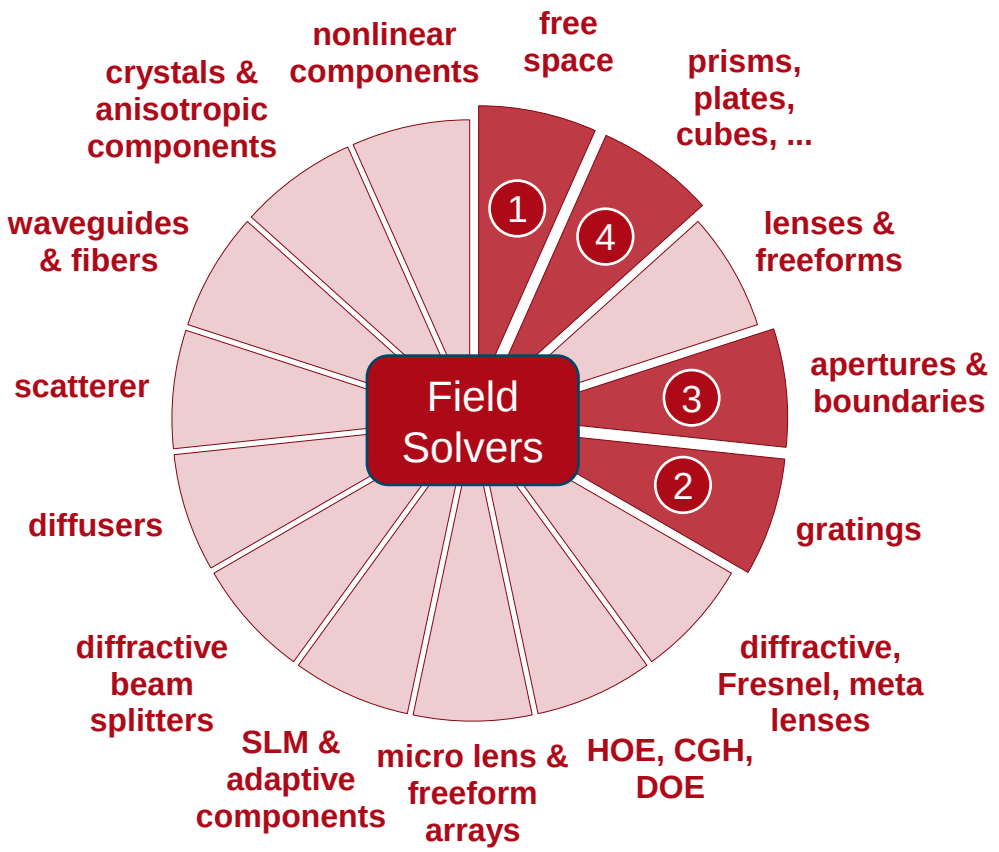
reflected light:



Higher orders are allowed to propagate with lower energy threshold; therefore, the interference effects can be observed (assumed light source is fully coherent).

VirtualLab Fusion Technologies





Document Information

title	Lightguide with 2D-Periodic Grating Structures (Diamond-Shaped) Based on Patent by Wave Optics
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software edition	• VirtualLab Fusion Advanced • Light Guide Toolbox Gold Edition
category	Application Use Case
further reading	- Grating Analysis and Smoothly Modulated Grating Parameters on Lightguides - Uniformity Detector for Lightguide Systems - Light Guide Layout Design Tool - Flexible Region Configuration - How to Set Up a Lightguide with Real Grating Structures